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THE PRODUCTION OF MAGNETIC FIELDS BY MECHANICAL MOTION

Professor W. Lochte-Holtgreven at the University of Kiel has carried out a number of experiments concerned with simulating astrophysical phenomena in the laboratory (see ESN 7, 39 (1953)). Two of the most interesting experiments are concerned with different ways of creating magnetic fields within a plasma by mechanical forces; the first deals with a compressible gas, the second with a "plasma" of practically zero compressibility. These experiments are of particular interest because stellar and interstellar magnetic fields very likely have a mechanical origin.

Magnetic Fields in Flame Gases

The flame of an oxygen-gas burner was brought into spinning motion by forcing the gas tangentially into a cylindrical tube, the gas inlet being interrupted at frequent intervals in order to produce separate whirls of burning gas which move along the inside of the tube. An induction coil surrounding the tube showed the existence of toroidal magnetic fields moving along together with (i.e., inside of) the plasma whirls.

Lochte-Holtgreven is of the opinion that these magnetic fields should be attributed to the velocity difference of ions and electrons within each whirl. The electrons are retarded relative to the ions because of their inherent diffusion into and back from cooler portions of the gas, and as a result a circular electric current is produced in the whirls concentric to the tube. The measured toroidal magnetic field is of the order of  $10^{-4}$  gauss provided that the conductivity of the flame is raised to about  $10^{11}$  electrostatic cgs units. This con-



ductivity can be realized by introducing potassium into the flame.

The influence on the experiment of the magnetic field of the earth, of the magnetic permeability of the gas, and other additional magnetic effects have been carefully considered. Details of the experiments will appear soon in the Zeitschrift für Physik.

#### Magnetic Fields in Liquid Mercury

An experiment concerned with the generation of magnetic fields in an incompressible medium was arranged as follows: in a cylindrical vessel filled with mercury the upper half was rotated by means of a stirring wheel while the lower half was prevented from rotating by means of diagonally fixed partitions. The angular velocity of the mercury in the upper half was fairly high (about 20-30 rev/sec.). Lochte-Holtgreven believes that a differential flow of electrons and ions takes place causing a toroidal electric current, in the absence of any external magnetic field. Preliminary measurements have shown a circular magnetic field (around the axis of rotation) of value about  $10^{-4}$  gauss. This value seems to fit reasonably well with theoretical expectations.

#### Broadening of Hydrogen Lines by Stark Effect

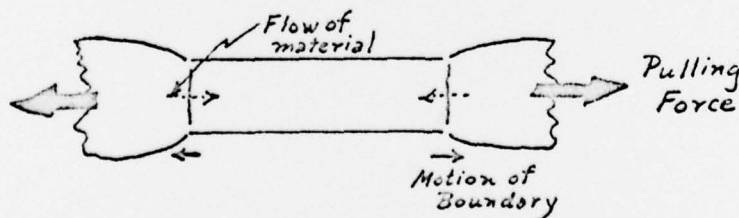
A spectroscopic problem important for astrophysics has been studied by H. Griem who measured the broadening of the hydrogen Balmer-lines by studying experimentally the dependence of the profile of the  $H\beta$  lines on the electron density of the emitting layer. He has explained these observations by a refinement of the theory in which the quadratic Stark effect and the change of transition probabilities, as well as the perturbation due to electron collisions, are taken into account. All these effects contribute to the broadening of Balmer-lines in regions of high ionization densities. This refinement of the theory is successful in explaining the complete intensity distribution of the  $H\beta$  line, including the amplitude of the central minimum and the difference between the two maxima on either side of the center.

## PHOSPHORS FOR TEMPERATURE MEASUREMENT

Professor H. Müller (Institute for Physical Chemistry, Marburg) and Dr. P. Brauer (Osram Research Laboratory, Mosbach) are utilizing luminescent phosphors to measure the temperature of nylon sheet while it is being stretched. When a nylon strip, which has been cut from an extruded sheet of the polymer, is stretched, it develops two distinct boundaries (see figure) which divide the strip into three zones. Under a constant pulling force, the central zone grows in length, although maintaining approximately constant cross-sectional area, accompanied by a visual flow of material across the boundaries. The temperature of the boundaries increases during the process.

The direct measurement of the temperature of the boundary is difficult by conventional techniques. Müller and Brauer are using the temperature characteristic of ZnS phosphors to measure this temperature. ZnS shows a different high temperature cut-off of its luminescence depending on the activator it contains. The nylon strip is coated with one of the phosphors, and the strip is photographed during stretching while it is illuminated by ultraviolet light. If the temperature of the boundary is above the cut-off temperature of the phosphor, the boundary will show up as a dark line. A series of photographs made during the stretching of various nylon strips, each coated with a different phosphor, allows a rough measurement of the temperature of the boundary and also gives some idea of the temperature gradient near the boundary.

Preliminary measurements show the feasibility of the method and have established the temperature of the boundary at about 150°C.



Profile of Nylon Strip during Pulling

## ELECTRON IMPACT SPECTROSCOPY

Professor H. Schüller and his collaborators have been studying electron impact spectroscopy for the past ten years at the Max Planck Institute for Spectroscopy (Hechingen, Germany). It should be remembered that these are emission spectra excited in a glow discharge tube. The discharge is established through an inert gas, and the substance under investigation flows through part of the discharge, without ever coming into contact with the electrodes. The experimental techniques have recently been refined in various ways; the method devised for the separation of possible "primary" and "secondary" steps in the chemical processes occurring in such discharge phenomena should yield particularly interesting results.

Emission spectra have been observed in a wide variety of organic substances. The complexity of the phenomena excludes the possibility of a complete analysis of single observations at the present time, and consequently a deductive approach is being followed. An attempt is made to obtain the same electron impact spectrum from the largest possible number of molecules and then to deduce the most probable species responsible for it. This approach has led to the identification of a spectrum due to the benzyl radical.

### The Spectrum of Diacetylene

The electron impact spectra which led Professor Schüller to postulate the occurrence of an interesting new species of formula  $C_2H_x$  ( $x = 1, 2$ , or  $3$ ) were described last year (Z. f. Naturf. 7a, 285 (1952)). This spectrum was observed using a wide variety of organic molecules containing double bonds, and Schüller favored the species  $C_2H$ . But as a result of using deuterium it was found that two new bands occur, and thus the species must contain two hydrogen atoms. The simplest molecule which would satisfy this requirement, acetylene, is eliminated as its spectra are well known and different from those under investigation. It was assumed that diacetylene ( $HC\equiv C-C\equiv CH$ ) is, in fact, the source of this spectrum, and it was subsequently shown that the intensity of this emission



band can be very greatly increased if diacetylene itself is introduced into the discharge. It is interesting to note that this diacetylene emission band is strong in the electron impact spectrum of naphthalene but very weak in that of anthracene.

The research activities of this Institute are more fully described in Technical Report ONRL-82-53, which is available from the Technical Publications Office, Office of Naval Research, Code 740, Washington 25, D. C.

#### ANODIC OXIDATION OF ZIRCONIUM

J. J. Polling and A. Charlesby (AERE, Harwell) have investigated the nature of the formation current in the electrolytic oxidation of zirconium. The combination of positive metallic ions of the anode and negatively charged hydroxyl ions of the electrolyte at the oxide surface produces metallic oxide and causes film growth. An electron current in the film is associated with the liberation of gaseous oxygen at the oxide surface. Thus, film growth is a measure of ion current while oxygen liberation has a similar meaning for electron current. Each of these currents was determined separately to provide a check on the results.

##### Electron Current

In the experiments the formation current was maintained constant so that the total charge passed was always known. The amount of oxygen liberated was determined by Winkler's chemical method and from this result the electron current was calculated. The difference between the total current and the electron current was ascribed to the ion current, and the latter by Faraday's law yielded the weight gain (oxide) of the specimen. A result of 0.46  $\mu\text{gm}$  per  $\text{cm}^2$  per volt was obtained.

##### Ion Current

Gravimetric measurements were made on zirconium specimens after being anodized at constant current in a normal solution of ammonium borate. Appropriate corrections were made for weight loss due to dissolution of the zirconium (or the oxide) in the electrolyte, and for weight gain due to entrapment of water in the film during



its formation; these in fact turned out to be very small and could have been neglected. In these experiments, the weight gain due to oxide formation was found to be 0.41  $\mu\text{gm}$  per  $\text{cm}^2$  per volt. This is in excellent agreement with the above result and verifies the basic assumption with regard to the electron and ion currents and their role in the process.

The current efficiency, which is given by the ratio of ion current to total formation current, increases with increasing total current density and tends toward a maximum efficiency of unity rather than the lower value deduced by others. In confirmation of a theoretical treatment by Charlesby for the ionic and electronic currents as a function of the field, it has been found that a plot of log ionic current against log electronic current is a straight line.

#### OBSERVATIONS ON THE FATIGUE PROCESS

P.J.E. Forsyth of the Royal Aircraft Establishment, Farnborough, has extended his previous metallographic observations on the fatigue of metals (J. Inst. Metals, 80, 181 (1951)) by examining more fully the mechanism of slip under cyclic stresses. By metallography, electron microscopy, and the multiple beam interference technique, he has investigated the similarities and differences of deformation produced by cyclic and static stresses. Most investigators have considered the deformation produced by the latter type of stress. The experiments were conducted on mono- and polycrystals of pure aluminum and, in addition, some work was done with silver chloride.

#### Slip Bands and Striations

Interferometric observations have shown that cyclic stresses produce slip on many closely spaced bands which have a grooved contour rather than the step form which is obtained by static stressing. The reason for this behavior is that the original step becomes a groove under a cyclic stress as the stress reversal causes slip to occur on a new parallel plane. Fatigue stressing produces slip bands (which themselves are packets of slip lamellae) congregated in striations. These striations (slip band clusters) increase in width with continuous cycling by the formation of additional slip bands; eventually the whole grain surface may be covered with bands.

The spacing of the striations is thus that which is established by the first stress cycle, and the number of striations is proportional to the stress level in any particular region in the specimen. Since all striations widen at approximately the same rate, the more heavily stressed grains are completely covered by slip bands in a shorter time than the lighter-stressed grains.

Forsyth has no evidence that each stress cycle produces additional bands. The number of visible slip bands is not directly proportional to the number of stress reversals. The first few fatigue cycles may produce a relatively large number of bands, and it appears that the formation of a slip band or even a slip lamella may be either an avalanche process or, more commonly, the integration of a number of small movements.

In the regions between the individual slip bands and the striations, the surface of the crystal is often undulated, the corrugations running in the direction of the slip bands. These corrugations, which can be observed by interferometry after cyclic or stress stressing, may be due to a more homogeneous form of slip or to internal stresses producing small amounts of strain. Very fine slip bands observed in these so called "slipless" regions, as seen by the electron microscope, show a spacing of the order of 1000 Å and may explain the observed fringe pattern.

#### Effect of Higher Frequency

Fatigue tests at higher frequencies (20,000 - 30,000 cpm as compared with 6,000 cpm used for the other experiments) produced slip bands markedly formed in striations which were resolvable only with the electron microscope. These striations produced at high frequency often showed a granular surface film giving a slightly stained appearance to the surface, suggesting that an increase in temperature had occurred. Such a temperature rise would account for the confinement of slip into the striations and would also increase the probability of polygonization, an effect which was also observed. Numerous very short slip bands were also found in these tests, and often conjugate slip was evident in the form of "feather edges" to the main slip bands. Grain boundary movement occurred, usually at the ends of striations, either into the striated grain

or its neighbor leaving a disturbed region behind. This boundary migration is thought to be due to the continual movement of dislocations to and from the boundary region.

#### Fatigue of Silver Chloride

Some supplementary fatigue tests on silver chloride clearly demonstrate that considerable polygonization occurs and that fatigue cracks initiate at the new crystallite boundaries, thus substantiating Forsyth's previously published work on the same phenomena for pure aluminum.

#### SYMPOSIUM ON HUMAN PERFORMANCE

The Ergonomics Research Society recently held a "Symposium on Human Performance, Its Measurement and Limitations" at Oxford University. This Symposium was widely attended by psychologists, physiologists, and industrial research workers from Great Britain and Western Europe, and had a few participants from the United States. Two of the interesting reports are summarized in the following.

#### Estimation of Daily Tolerable Work by the Photo-Electric Pulse Counter

Dr. E. A. Müller of the Max-Planck Institut für Arbeitsphysiologie, Dortmund, reported observations of the heart rate during heavy work on a bicycle ergometer and during recovery. He found that for each individual under each pattern of working there was a maximum level of work per hour (endurance limit) which could be sustained for hours at a steady rate, with a steady pulse rate, and with a total recovery pulse sum not exceeding 100 beats, the recovery pulse sum being the total number of heart beats above the resting level occurring during the recovery period. A work level exceeding the endurance limit is associated with an increasing pulse rate during the working period (fatigue rise) and an increased recovery pulse sum. Müller therefore presented the idea of a pulse "steady-state" as a practical indicator in estimating the tolerable work/hour in any situation.



Physiological Measurements as a Basis of Work  
Organization in Industry

Dr. G. Lehmann of the same Institute reported the results of studies on the working levels of workers in forging mills, motor car plants and electrical factories. He found that 4800 kcal per day was the maximum tolerable amount for daily repeated work. However, the normal net daily work output of a workman at heavy work is about 2000 kcal per day, i.e., about 4 kcal/min, and it has been found that this level can be maintained at constant pulse rate. If the output per minute periodically exceeds 4 kcal/min then adequate rest periods are required to reduce the average level and maintain constant pulse rate. If, however, under this level of working an increasing pulse rate is observed, then search for other sources of stress must be initiated. Such stresses arise when the worker becomes dehydrated, when the environmental temperature is too high, or when improper working posture is maintained.

A worker customarily adjusts his working rate to a comfortable level by various tactics which provide virtual rest periods. Much of this resting is accomplished under the guise of accessory work. Dr. Lehmann introduced definite resting intervals during each working hour in a department of an electrical parts factory. The results illustrated by the following table show a decrease in the accessory working time and an increase in daily output.

	Effective Working Time	Accessory Working Time	Resting Loafing	Time Assigned Rest	Work Output (parts)
Control period	81.7%	7.6%	10.7%	0%	3008
Period with 5 minutes assigned rest during each hour	85.4%	2.7%	3.6%	8.3%	3115

Further information on this Symposium is to be found in Technical Report ONRL-84-53, available from the Technical Publications Office, Code 740, Office of Naval Research, Washington 25, D. C.



### MOTION SICKNESS

Dr. G. de Wit of Utrecht, reasoning from the fact that animals are in general liable to seasickness but animals in which the labyrinths have been destroyed are no longer subject to seasickness, has concluded that in addition to the variable extent to which psychic influences play a role in seasickness in man, that seasickness is basically a labyrinth disease. Using cupulometry, as developed by van Egmond, Groen and Jongkees, to investigate the labyrinth function in members of the Royal Netherlands Navy, de Wit has found that persons subject to chronic seasickness show definite cupulometric abnormalities. Eighty per cent of persons known to suffer from chronic seasickness show a cupulogram with a much steeper curve than that of normal persons. The other twenty per cent of persons who suffer from chronic seasickness show pathological abnormalities of one type or another, often with differences in function between the right and left labyrinth. In the group comprising eighty per cent of seasick subjects there is a hypersensitivity of the perception of angular accelerations, in most of the subjects presumably because of some abnormality of the function of the semicircular canals. Others in this majority group are presumably hypersensitive to stimulation of the otoliths elicited by means of the parallel swing which causes an increased intracranial blood pressure in sensitive subjects. The smaller group comprising twenty per cent of the total has a demonstrable disfunction of the labyrinth. Subjects which show abnormalities of the cupulograms may be considered poor risks from the point of view of seasickness.

This work was presented at the Fifth International Congress of Otorhinolaryngology held in Amsterdam, 8-13 June 1953, and is part of Technical Report ONRL-91-53, available from the Technical Publications Office, Code 740, Office of Naval Research, Washington 25, D. C.

### ERRATUM: MEASUREMENT OF INTERCELLULAR pH BY MEANS OF A MICROTUNGSTEN ELECTRODE

The reference quoted in the item with the above title (ESN 7, 138 (1953)) should read J. R. Baylis, J. Industr. Eng. Chem. 15, 852 (1923).

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington, since the last issue of ESN. Copies may be obtained from the Technical Publications Office, Code 740, Office of Naval Research, Washington 25, D. C.

ONRL-90-53 "Chemistry Research at Birkbeck College, London" by R. W. Mooney

ONRL-93-53 "A Cardiometer" by J. L. Nickerson

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